

Instrumental Efficient Assessment of Mental Condition of Computer-Aided Control Systems Operator

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SUMMARY

This material contains the description of instrumental technique of operative assessment of the mental condition of computer-aided control systems operator. The assessment is based on the study of processes of formation and functioning of mental dynamic images when an operator becomes involved in an activity on the basis of observation by perception. The data concerning the structure and dynamics of formation and functioning of mental dynamic images helps to determine in numbers the following components of mental condition: abilities for adaptation, self-organization of behavior, mental tension, operative dynamic memory etc. This method is realized as a program product working under Windows 95/98/ME operating system.

STATE OF THE PROBLEM UNDER INVESTIGATION

Experimental studies of the mental mechanisms of regulation of operator's actions have been carried out for quite a long time – almost from the moment when the very notion “operator's activity” appeared. However over a long period of time engineering psychological papers were directed almost solely at the study of sensory and motor processes. Considering an operator as a subsystem in the systems “man – machine” and “man – automaton” engineering psychology dealt mainly with the “sensory input” in this subsystem, i.e. with the ways of information presentation to a man and its localization on the panel of indication facilities; as well as with the “motor output” – peculiarities of the controls and their location on the consoles; the relation between “sensory input” and “motor output”. It is precisely this kind of studies that made for the first decisive successes of engineering psychology.

At the same time it is well known that the more complex a controlled object the more important central processes of information processing become, taking place between reception of the incoming information from the object and reaction to this information, taking into account its rational influence on the object. One of the most important tasks of engineering psychology consists in the study of mental reflection of the controlled object itself in the operator's consciousness as an image. Unlike the overwhelming multitude of manual production operations in telecontrolled systems an object's image with which an operator has to work does not arise from the direct influence on operator's analyzing systems. This fact however not only fails to deprive an object's image of its function in the information processing, but on the contrary, considerably increases the role of this function. Only thanks to the projection on the controlled object's image of signaling information about consecutive changes in its directly controlled parameters an operator can imagine the object's state at each given moment.

Experience shows that retention in consciousness of the dynamics of object's image often presents considerable difficulties for an operator, which directly affects the quality of his or her fulfillment of the corresponding tasks. Thus, *the adequacy* of content of the object's image (image-bearing information)

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to the concrete image assignment in the object-oriented system is an essential characteristic of the image as an action regulator. This major characteristic of object reflection in the image is called *the operativeness of the image*. Accordingly, *an operative image* – is an ideal specialized reflection of the object (process, phenomenon etc.) transformed during some action, forming in the course of fulfillment of a specific object-oriented action and task-subordinate action.

To be more concrete as applied to the activity of computer-aided control systems operator *an operative image* is defined as a “mental information complex, in which all information about the object of control, which can become important when working on different operator’s tasks, is concentrated and organized in accordance with the tasks and conditions of an operator’s activity” [1].

Naturally, *dynamic* operative images are of special interest, i.e. images, in which the dynamics of the objects (the process happening in them) finds its reflection. The most elementary dynamic images take place when a process is imagined as a motion of a point on the plane. In this case the object’s states, which sequence characterizes its dynamics, are reflected as separate positions of a point and the process as a whole as a line formed by the aggregate of these points. In case the process in the image is reflected as a trace of a point moving relatively to a certain coordinate system the object’s states appear as conjugated values of functionally connected parameters. If reflection of two parameters is insufficient for the effective control, a dynamic image takes a more complex view.

Very often a process controlled with the help of a dynamic image proves to be variational: under the influence of disturbing forces or some other reasons its parameters receive different values within permissible limits. For effective control in such cases a *generic* dynamic image is being formed absorbing all amount of normal variations.

As a variety of an operative image one should consider the so-called *conceptual model* – a correlated with the object its complex dynamic image, which reflects the pre-assigned object’s dynamics, nominal structure of the process, i.e. the one, which must be or become in operator’s conception [2].

Reflection of the temporal structure of the process, i.e. sequence of states of the controlled object, forms the main or basal component of a conceptual model. Semantic richness of the model, which in certain cases is reduced to reproduction of the clear sequence of abstractly conceived states (state *B* after state *A*, state *C* after state *B* etc.) has a subordinate meaning, as well as the circumstance that the temporal sequence itself can be reflected either in absolute or relative time scales compressed or stretched in comparison with a real process.

Temporal scan of information organized in the conceptual model always happens in the course of control with a certain lead of the real object’s dynamics relative to an operative image.

Reflection in the conceptual model of the process as a sequence of object’s states corresponds to the dynamics of individual’s active attitude to them. Change in the mental tension of the individual constitutes a psycho-energetic basis of the model or its energy background. The fact that dynamics of mental tension is clearly realized by the individual and is one of the components of his or her state raises no doubts.

Operator’s mental condition is a direct integral reflection, a sort of trace of an objective situation and represents a product of complex mental processes.

Mental condition develops as an integral multi-dimensional response, which occurs under the impact of environment, available functional opportunities and operator’s individual characteristics. Unlike vegetative responses, which accompany any behavior act and express the energy of any process, mental conditions are determined by the information factor and organize an individual’s adaptive behavior

on a higher mental level taking account of his or her personal qualities, motives, convictions and concrete attitude to what is going on.

A structure of mental condition consists of three levels. The first one, a physiological level, includes neurophysiological characteristics, morphologic and biologic changes, shifts of physiological functions.

The second one, a psychophysiological level – vegetative responses, changes in psychomotor and sensory systems.

On the third one, a psychological level, mental conditions occupy one of the main places among mental phenomena. Mental conditions determine the nature of operator's activity to a considerable degree. The study of the problem of mental conditions helps to understand the questions of norm and pathology of mental activity better.

Mental condition has a dynamic procedural nature and can pass from one quality to another.

Mental condition in any case characterizes the operator's psyche, determines peculiarity of different mental processes.

A change of mental condition under the influence of certain work conditions affects the structure of mental reflection and image, which controls a specific behavior pattern in a specific type of situation.

A change of mental condition leads to a deformation of mental reflection. The essential feature of such deformation is that operator's consciousness focuses on only one element of the situation, which hinders its comprehensive awareness and impedes an adequate reflection of the situation and proper decision-making. A distorted image-target is formed, which displaces an adequate image.

Thus, the most objective diagnostics of operator's mental condition can be achieved in case he or she is being involved in some specific activity with the possibility of instrumental assessment of the character of formation and destruction of mental image as behavior regulator [3–6].

DESCRIPTION OF THE METHODS USED

Activity of computer-aided control systems operator is based on the fulfillment of tracking operations. Working on tasks like tracking makes great demands of an individual – continuous change of the input signal requires continuous matching of individual's response movements with the sensory data, which reflects the changes in the working environment at each given moment of time, i.e. during tracking not only an operator's sensorial area but realization of motional behavior itself becomes dynamic. When tracking operations are being performed control influences on the regulated object take place indirectly through the control: an operator in the dynamics of his or her actions reflects the dynamics of change of the object's states.

Necessary conditions for the effective fulfillment of tracking operations include: continuous assessment of current signal states, continuous agreement of movements with changing signal states, prevision of the course of signal change, readiness for re-organization of motor behavior. Successful completion of tracking operations means that spatial and temporal structure of control movements must match the dynamics of signal change.

Realization of tracking often comes to the task of spatial matching on the screens of special structures of two signals, one of which is defined by a certain program, the other one is controlled by an operator. It is a large number of variables in tracking tasks that determines their variety: discrete or continuous character, tracking type (pursuit or compensatory), different modality of the input signals, different dynamics of the systems etc.

When speaking about tracking types it should be noted that if in case of compensatory tracking a person receives information only about a mistake, in case of pursuit tracking he or she also knows what comes to the system input and what happens in the output. According to this an individual's behavior in case of different tracking types differs.

Advantages of pursuit tracking over the compensatory one can be formulated in the following way [7]:

- 1) An operator can observe and train in the regularity and statistical properties of the input signal.
- 2) He or she can forecast at a given moment the subsequent signal path, i.e. in case of pursuit tracking an operator has more opportunities for extrapolation. Subsequent signal path can be predicted both on the basis of visible signal rate and knowledge of the input signal parameters.
- 3) An operator can directly observe his or her response actions, which are not masked off by the input signal, like it happens in case of compensatory tracking. Thus one can study the system's dynamics and train to react properly, as he uses a feedback "input information – results of his actions" right away.
- 4) In case of mistake an operator can see directly whether it is caused by signal change or his or her own actions.

We consider that the most convenient model of activity based on a dynamic object's image is the processes of pursuit tracking with the following tracking by perception (one can speak about tracking by perception in those cases when in the process of tracking, for one or another reason, information from the target no longer reaches an operator and the latter behaves being exclusively controlled by the dynamic target's image, which had been shaped in one's consciousness earlier). It ensures both the qualitative and accurate quantitative analysis of the received experimental data. Opportunities of the qualitative and quantitative analysis of the structure of control actions increase and enrich upon parallel synchronous registration of movement (relocation) of the control. Synchronous registration of the "motor input" data allows to study the microstructure of control movements, to measure the rate, duration, amplitude of operator's partial movements, number and duration of pauses, response nature, duration and nature of transient processes etc. [8].

This model has been realized with the help of a specialized program product working under Windows95/98/ME operating system. An operation principle of the experimental plant consists in the following:

- the input information is fed to a computer screen from a signal source as a point-mark moving in the specified path;
- the individual's effective activity is displayed on the screen as a point-sight moving in the result of one's action on the control;
- a transfer function of the experimental plant is equivalent to an amplifying link, i.e. the equipment used does not produce distortion when the input information is reproduced by an individual. Such structure of the control loop allows clear detection of the individual's qualities functioning as a link of the closed control loop;
- the control can move in the direction «forward backward» and «from left to right», it also has a potentiometer output, under the influence of its voltage a point-sight moves on the screen of indicator;
- a program product by way of comparison of the input information dynamics and professional activity fixes:
 - input information and professional activity dynamics (synchronously);
 - mental dynamic image formation time;

- mental dynamic image destruction time;
- professional activity strategy;
- duration of recovery, stabilization and destruction phases in the process of mental dynamic image formation and destruction;
- latent period duration;
- time of influence on the control;
- correction time;
- dimension of spatial mistakes;
- number of operator's sharp movements.

We make conclusions about the character and structure of dynamic mental images, peculiarities of their formation, functioning and destruction indirectly, by means of qualitative and quantitative analysis of experimental data, which characterize the dynamics of motor components of control actions throughout the experiment. Work of the tested individuals subdivides into two periods: 1) during the first one a person performs tracking, viewing both the reference signal (continuous or discrete) and the signal corresponding to the movement of the control; 2) upon completion of the first period both signal disappear but the operator keeps watching, although now he or she is expected to observe the image of dynamic situation of the first period, i.e. the dynamic image formed earlier. After the experiment has been completed the dynamics of one's professional activity is displayed on the screen in diagrams (fig. 1 and 2) and the abovementioned quantitative characteristics – in tables.

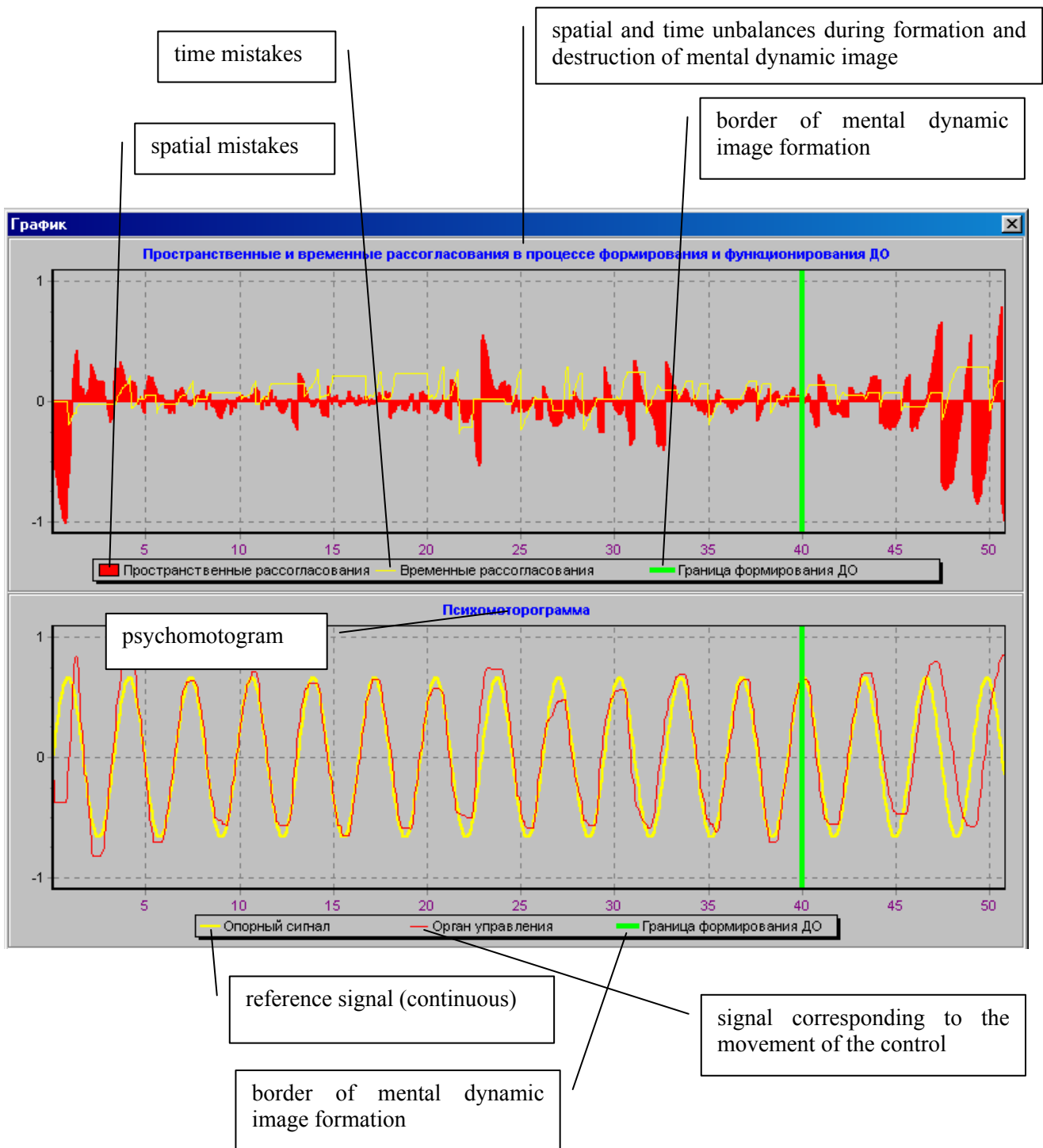


Figure 1: Dynamics of One's Professional Activity (Continuous Reference Signal).

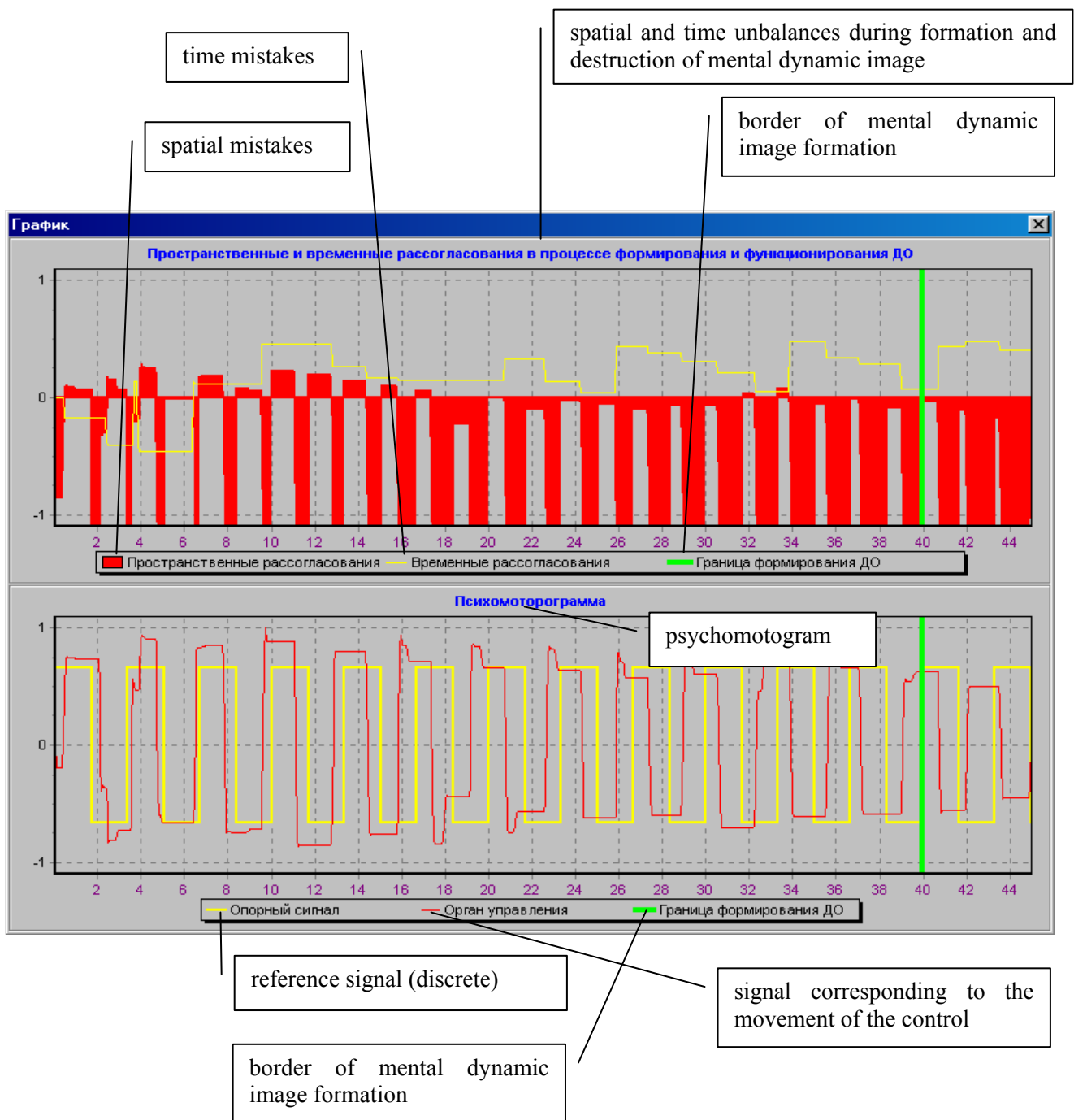


Figure 2: Dynamics of One's Professional Activity (Discrete Reference Signal).

DISCUSSION OF THE RESULTS RECEIVED

Relation between the time of adequate reflection process and time of dynamic image formation has a non-linear character. Experiments have shown that optimal time of dynamic image formation is 40 seconds.

In the course of experiments we observed different strategies of the processes of adequate reflection, which can be classified on the basis of prevalence of prediction or delay elements.

The process of adequate reflection has a phase character, consisting in alternation of destruction, recovery and stabilization phases: from phase to phase a fluctuating process is going on – with deviations, delays, remissions. Recovery and stabilization phases exert great influence on the duration of adequate reflection process.

In general a dynamic structure can be presented by the following formula:

$$0(t) \longrightarrow (A_0) \longrightarrow (t_1 K_p^{-1} K_{0p}^{t\Sigma(1)}) \longrightarrow \dots \longrightarrow (t_n K_p^{-n} K_{0p}^{t\Sigma(n)}),$$

first phase

n-phase

where A_0 – initial mismatch, corresponding to the moment when tracking based on a dynamic image begins;

t_n – n-phase duration;

K_p^{-n} – destruction factor conditioned by n-phase;

$K_{0p}^{t\Sigma(n)}$ – current value of destruction factor corresponding to the time $t(n)$ of n-phase termination.

The data concerning the structure and dynamics of mental dynamic image formation and functioning help to determine in numbers the following structural components of operator's mental condition [3,4,6]:

- 1) Adaptive mental abilities, meaning an operator's ability to forecast a change of external events and to respond to them adequately.
- 2) Self-organization of one's behavior, meaning an operator's ability to constantly pursue effective activity.
- 3) Mental tension, meaning an operator's current condition, affected by external factors and type of personality.
- 4) Operative dynamic memory, meaning an operator's ability to reflect adequately during a certain time span the spatial and temporal properties of the dynamic process after the information about it has disappeared.

Apart from these indications the method in question makes it possible to set the time for self-adjustment to the input information, assessment type of external events, as well as fatigability.

In the course of the performed studies it is proven that there is a correlating relation between the strategies of mental actions, which characterize a mental dynamic image, and operativeness of operator's activity. For illustration of this statement we can refer to the studies carried out by Kremen, M.A. [9], in which a comparative analysis of flying results of students-pilots and their strategies of tracking by perception is made. Kremen, M.A. has discovered that students working with a predictive tracking strategy master plane piloting considerably more quickly, than students working with a lagging tracking strategy.

CONCLUSIONS AND RECOMMENDATIONS

The method described above has a number of obvious merits: high validity of results, operativeness, low fatigability of participants of the experiment, as well as the simplicity of the equipment maintenance. It can be used both for assessment of mental condition of computer-aided control systems operators and assessment of mental and motor functions of people, whose professional activity includes fulfillment of tracking operations.

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